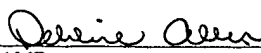


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APPLICATION FOR LETTERS PATENT

FOR

**ELECTRODE GUIDE FOR SPARK-EROSION  
MACHINES AND A METHOD FOR THE SPARK-  
EROSION OF WORKPIECES**

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## **ELECTRODE GUIDE FOR SPARK-EROSION MACHINES AND A METHOD FOR THE SPARK-EROSION OF WORKPIECES**

### Cross Reference to Related Application

5                    This application is a continuation of copending International  
Application No. PCT/DE02/00260 filed January 25, 2002 and claiming a priority date  
of January 25, 2001, which designates the United States.

### Technical Field of the Invention

10                   The present invention relates to an electrode guide for spark-erosion  
machines and a method for the spark-erosion of workpieces

### Background of the Invention

15                   A wide variety of spark-erosion machines are known in the prior art.  
Such machines are used for example to generate bores. In such cases for example  
ceramic tubes are used as electrode guides or carbide collet chucks with side  
tensioning mechanisms are used. With these known electrode guides, the tolerances of  
the tensioned position of the electrode in relation to the axis of rotation are around 5  
µm, which means that they are relatively inaccurate for the generation of microbores.

20                   The production of microbores is particularly problematic and so in  
particular is the production of conical microbores with accurately defined front or rear  
widening. It has not as yet been possible to mass-produce such microbores with an  
acceptable tolerance of 1 µm. Conical microbores in particular can only be generated  
subject to adjustments to the erosion parameters. For example conical bores are  
generated by means of a removal capacity that increases with the depth of the bore or  
a rotating wire electrode is energized to oscillate as the depth of the bore increases,  
25                   in order to describe a cone shaped path. However with such methods only bores with  
inaccurate dimensions and relatively large tolerances of over 5 µm can be obtained.

For example when producing microbores for fuel injection valves, tolerances in the range of 1  $\mu\text{m}$  would be desirable. There is therefore a need for an electrode guide and a spark-erosion method which achieve such tolerances of 1  $\mu\text{m}$ .

### Summary of the Invention

5                   It is therefore the object of the present invention to provide an electrode guide or a spark-erosion method which provides play-free guidance with a simple structure and low-cost manufacture, to generate bores or recesses with the smallest possible tolerance.

                  According to the invention therefore an electrode guide or a guide  
10   device for an electrode on a spark-erosion machine is provided, which has a prism-shaped guide comprising a holding component and a pressure component. The electrode is located and guided between the pressure component and the holding component. A grooved recess is configured in the holding component or in the pressure component and the pressure component is pressed against the holding  
15   component by means of a pre-tensioning device. In this way according to the invention a defined position can be ensured for the electrode with a tolerance of  $\leq 1 \mu\text{m}$ , even when the electrode is advanced during the course of the spark-erosion process, as the electrode is guided in a play-free manner in the electrode guide. With rotating electrodes in particular a concentricity of  $\pm 1 \mu\text{m}$  can be accurately achieved.  
20   This means that microbores for example can be produced with maximum accuracy. As the grooved recess is configured either in the holding component or in the pressure component, according to the invention a minimum number of contact points can be achieved between the electrode and the electrode guide. It is particularly advantageous to provide three contact points.

25                   A grooved recess is preferably configured both in the pressure component and in the holding component.

In order to have precisely three contact points between the electrode and the electrode guide, the grooved recess is preferably configured with a V-shaped cross-section and is created either only in the holding component or only in the pressure component.

5                   In order to provide reliable and continuous guidance of the electrode in the electrode guide, the pressure component is pressed against the holding component by means of a spring element or by means of a weight. In this way precise guidance can be ensured.

10                   In order to provide optimal pressure forces in every instance for electrodes with different diameters, the pressure force of the pressure component can be adjusted. For example, when the pressure force is provided by means of a weight, this can be arranged so that it can be displaced by means of a lever arm, thereby exerting a different force on the pressure component depending on its position. In order to allow fine adjustment, the weight can preferably be moved via a screw thread.

15                   A spring steel sheet for example can also be provided as the spring element, the spring force of which can be adjusted by means of movable stops. The pressure force is selected in each instance so that the spark-erosion process can proceed without malfunction.

The electrode guide is preferably arranged in a rotating manner.

20                   It is particularly preferable for the electrode to be arranged in a rotating manner. If the electrode guide is also arranged in a rotating manner, the electrode preferably rotates at the same speed as the electrode guide.

25                   A pivoting device is also provided to pivot the electrode guide. The electrode guide is then preferably pivoted through an angle of pivot of  $\pm 2^\circ$  about an axis in the direction of advance, in which the electrode wire is arranged. In the case of a rotating electrode the axis in the direction of advance and the axis of rotation

correspond. The pivoting device can be used to adjust the electrode guide through an angle in relation to the axis of rotation. This means in particular that bores with taper can be generated, with the option of generating both bores which decrease conically from the electrode guide side (bores with front widening) and bores, which increase  
5 conically from the electrode guide side (bores with rear widening). The conical bores can be produced with a smooth surface line. This means that bores for injection nozzles in particular can be produced with maximum accuracy according to the invention.

In order to be able to displace the electrode guide parallel to the axis in  
10 the direction of advance or parallel to the axis of rotation as well, an alignment device is also preferably provided.

It is particularly preferable for the alignment device to be arranged in a rotating head. The alignment device can then be structured for example so that it has four screws arranged in the rotating head, each of which is in contact with a different  
15 side of the electrode guide and which center the electrode guide between them. This means that the position of the electrode guide can be displaced in any radial direction parallel to the axis of rotation of the electrode.

The central area of the pressure component facing the electrode is advantageously configured with a further recess. This means that the electrode is only  
20 pressed against the holding component and guided via two areas of the pressure component. In other words the electrode is only pressed against the holding component at both ends of the pressure component.

It is particularly preferable for the electrode guide to be arranged in the rotating head, which is held in a bridge. Precision bearings are then used to hold the  
25 rotating head.

The bridge is preferably held by means of play-free spherical guides in a spindle of the spark-erosion machine so that it can be displaced in the direction of the axis.

The electrode guide is preferably located axially between the spindle  
5 and the workpiece to be machined.

A stop is advantageously provided to limit bridge advance.

It is particularly preferable for the stop to be adjustable.

In order to allow a simple rotating head structure, the rotating head is preferably driven via a driver on the spindle.

10 The electrode guide is advantageously made of an  $\text{Al}_2\text{O}_3$  ceramic or carbide or steel.

According to the inventive method for spark-eroding recesses, in particular microbores, in workpieces, an electrode guide has a holding component and a pressure component, with a grooved recess being provided in the holding component  
15 and/or in the pressure component. An electrode is arranged between the holding component and the pressure component. The pressure component is pressed against the holding component by means of a pre-tensioning device. The electrode is also arranged in a rotating manner, with only the electrode being advanced for spark-erosion purposes and the electrode guide remaining at a defined distance from the  
20 workpiece in the direction of advance. In this way, bores with a tolerance of  $\pm 1 \mu\text{m}$  can be produced according to the invention.

Preferably the electrode guide is arranged in a rotating manner with the inventive method.

Preferably the electrode guide can be pivoted by means of a pivoting device, so that the electrode guide, and therefore also the electrode emerging from the electrode guide, is positioned obliquely in respect of the axis of rotation. This means that conical bores in particular both with front widening and rear widening can be produced with a rotating electrode guide. To produce bores with rear widening, the electrode guide is advanced parallel to the axis of rotation of the electrode, so that the point of entry of the electrode at the workpiece, which has been positioned obliquely by means of the pivoting device, is precisely on the axis of rotation of the electrode guide. If the electrode is now advanced, the rotating electrode describes a spherical surface movement, generating a conical bore with rear widening, with the central axis of the generated bore on the axis of rotation of the electrode guide. When a conical bore with front widening is to be produced, the electrode guide is advanced parallel to the axis of rotation so that an entry position of the electrode into the workpiece is on the large diameter of the bore (27) to be produced. In this way according to the invention for instance conical bores with rear widening of 0 to 100  $\mu\text{m}$  can be produced to a bore depth of 1 mm with a straight surface line. It should be noted that the parallel displacement or pivot of the electrode guide can also be produced by means of an automatic controller and can also be modified during the machining process.

## 20 Brief Description of the Drawings

The invention is described below using preferred embodiments in relation to the drawing. The drawing shows:

**Figure 1** a schematic sectional view of a spark-erosion machine with an inventive electrode guide according to a first exemplary embodiment of the present invention;

**Figure 2** an enlarged sectional representation of the inventive electrode guide shown in Figure 1;

- Figure 3** an enlarged side view of the electrode guide according to the first exemplary embodiment;
- Figure 4** a schematic representation of the inventive electrode guide for the production of a bore with rear widening;
- 5 **Figure 5** a schematic representation of the inventive electrode guide for the production of a bore with front widening;
- Figure 6** an enlarged side view of an electrode guide according to a second exemplary embodiment of the present invention;
- Figure 7** an enlarged side view of an electrode guide according to a third  
10 exemplary embodiment of the present invention; and
- Figure 8** a top view of an inventive electrode guide according to a fourth exemplary embodiment of the present invention.

#### Detailed Description of the Preferred Embodiments

A first exemplary embodiment of an inventive electrode guide  
15 according to a first exemplary embodiment is described below with reference to Figures 1 to 3.

As shown in Figure 1, the inventive electrode guide 1 has a holding component 2 and a pressure component 3. The pressure component 3 is pressed against the holding component 2 by means of a pre-tensioning device 6. A rotating  
20 electrode 4 in the form of a wire is guided between the holding component and the pressure component. The electrode 4 is driven via an electrode spindle 18.

There is a recess 25 (see also Figure 3) in the pressure component 3, so that the electrode is only in contact with the pressure component 3 at its two ends. As shown in Figure 2, the holding component 2 has a grooved recess 5, which is

configured with a V-shaped cross-section and holds part of the electrode 4. This means that there are precisely three contact points between the electrode guide 1 and the electrode 4.

5 As shown in particular in Figure 3, the pre-tensioning device 6 has a spring element 7, the spring force of which acts via a securing device 9 on the pressure component 3. This ensures that the electrode 4 is guided securely in the electrode guide 1 with no possibility of play on the part of the electrode 4 in the electrode guide 1. The strength of the spring force can be adjusted via an adjustment screw 28. A screw 29 is used to secure the spring element.

10 As shown in Figure 3, a pivoting device 10 is also provided. The pivoting device 10 has a first screw 12 and a second screw 13. By using the screws for adjustment purposes the electrode guide 1 can be pivoted about a pivot point 11. This means that the electrode guide 1 can be inclined through a specific angle in relation to the axis of rotation X-X of the electrode 4.

15 An alignment device 14 is also provided, which can be adjusted by means of four adjustment screws 24. Only one adjustment screw 24 is shown in Figure 1 to simplify the illustration. The alignment device 14 can be used to displace the electrode guide 1 parallel to the axis of rotation X-X.

20 The electrode guide 1 is located above the alignment device 14 in a rotating head 15. The rotating head 15 is held in a bridge 17 by means of precision bearings 16. The bridge 17 is held with two guide rods by means of play-free spherical guides 20 in the spindle of the spark-erosion machine so that it can be advanced by spring action in the direction of the axis. The spark-erosion spindle 18 then drives the rotating head 15 via a driver 19. As a result the electrode guide 1 also rotates at the  
25 same speed as the electrode 4. The electrode 4 can be clamped by means of an electrode clamp 23 and be displaced gradually or continuously out of the electrode guide 1 as a result, to erode a bore in a workpiece 26.

For spark-erosion purposes the bridge 17 comes up against an adjustable stop 21, located at a machine table 22. The distance between the electrode 4 and the workpiece 26 can therefore be adjusted continuously according to the requirements of the spark-erosion process. For spark-erosion purposes the rotating  
5 electrode 4 is now advanced by means of the electrode clamp 23. The electrode guide 1, which is also rotating, then remains at a defined distance A from the workpiece 26 (see also Figure 1). While the electrode is being advanced, the electrode clamp 23 does not influence the position of the electrode in relation to the axis of rotation X-X, so that the concentricity of the electrode 4 can be maintained precisely at  $\leq 1 \mu\text{m}$  by  
10 the electrode guide 1. Nor is the electrode position influenced during the spark-erosion process due to drive action via the drivers 19 by the disconnected spark-erosion spindle 18. This means that microbores in particular can be produced with maximum accuracy. The rotating electrode 4 means that any existing minimal errors of form in the electrode 4 are not transferred to the bore form, as the electrode rotates and thereby  
15 improves the circular form of the bore. It should be noted that the inventive electrode guide 1 is also suitable for stationary electrodes and other hole forms or recesses can therefore be produced, e.g. using profiled electrodes.

Also conical bores and in particular conical bores with rear widening can be produced by means of the inventive electrode guide 1 and the inventive  
20 method. In the case of conical bores with rear widening, the bore is configured so that the bore diameter increases as the depth of the bore increases. Such a bore 27 with rear widening is shown for example in Figure 4.

To produce the bore with rear widening shown in Figure 4, the electrode guide 1 is first pivoted about the pivot point 11 by means of the screws 12,  
25 13 in the pivoting device 10. The extent of the pivot movement depends on the nature of the taper required. Usually the electrode guide 1 is pivoted through an angle  $\alpha$  of  $0^\circ$  to approx.  $2^\circ$ . The electrode wire is slightly bent as a result. The electrode guide 1 is then displaced parallel to the axis of rotation X-X by means of the alignment device

14. The electrode guide 1 is advanced parallel to the axis of rotation X-X until the point of entry of the electrode 4 into the workpiece 26 is precisely on the original axis of rotation X-X (see also Figure 4). The electrode guide 1 therefore rotates about the axis of rotation X-X, with its tip close to the axis of rotation. If the rotating electrode 4  
5 is now advanced, it describes a movement on a spherical surface, which causes a conical bore 27 with rear widening to be generated.

Figure 5 shows the production of a bore with front widening. In the same way as when a bore with rear widening is produced, the electrode guide 1 is pivoted through an angle  $\alpha$  and then displaced parallel to the axis of rotation X-X. This  
10 causes parallel displacement of the electrode guide 1 so that the entry point of the electrode 4 into the workpiece 26 is on the outer diameter of the bore 27. The electrode guide 1 therefore rotates at a certain distance about the axis of rotation X-X and describes a movement on an inverted spherical surface (see also Figure 5). After production of the bore 27 the electrode 4, advanced during spark-erosion, is precisely  
15 on the axis of rotation X-X.

As the electrode 4 is also guided continuously by the inventive electrode guide 1 during the production of conical bores, these bores can be produced quickly and easily with an accuracy of 1  $\mu\text{m}$ , which was not possible with the methods known previously from the prior art, which increase or decrease the removal rate as  
20 the depth of the bore increases or which cause the electrode to oscillate as the depth of the bore increases. The present invention therefore represents particular progress towards the rational production of bores and in particular microbores using spark-erosion methods.

Figure 6 shows an electrode guide 1 according to a second exemplary  
25 embodiment. Identical components or components with identical functions are shown with the same references as in the first exemplary embodiment.

Unlike the first exemplary embodiment, in the second exemplary embodiment the pre-tensioning device 6 is configured by means of a weight 8. The weight 8 acts via a lever arm and a securing device 9 on the pressure component 3, to press it against the holding component 2 (see also Figure 6). The weight 8 is  
5 configured here as a cylindrical body with an internal through opening. A thread is cut into the through opening, by means of which the weight can be adjusted, so that the active length of the lever arm can be changed and the pressure force of the pressure element 3 can be adjusted. In order not to obstruct the pivot movement of the electrode guide 1, the pre-tensioning device is jointed (see also Figure 6).

10                Otherwise the electrode guide 1 of the second exemplary embodiment corresponds to that of the first exemplary embodiment, so there is no need for a further description.

Figure 7 shows an electrode guide 1 according to a third exemplary embodiment. Identical components or components with identical functions are shown  
15 with the same references as in the first or second exemplary embodiment.

Unlike the exemplary embodiments described above, in the third exemplary embodiment the electrode guide 1 comprising two half-liners 2 and 3 is pre-tensioned by means of an adjustment screw 30. The electrode guide 1 comprises a number of successive cylindrical bodies, each of which has a smaller diameter than the  
20 previous cylindrical body. The electrode guide is preferably made up of two cylindrically offset (staged) half-liners. This electrode guide is used in particular to produce cylindrical microbores. Otherwise the electrode guide 1 of the second exemplary embodiment corresponds to that of the first exemplary embodiment, so there is no need for a further description.

25                Figure 8 shows an electrode guide 1 according to a fourth exemplary embodiment. Identical components or components with identical functions are shown with the same references as in the previously described exemplary embodiments.

Unlike the exemplary embodiments described above, in which the electrode guide 1 has a cylindrical outer form (see also Figure 7), the electrode guide 1 in this exemplary embodiment has a rectangular form. It should be noted that other external forms, e.g. triangular, are also possible, depending on the recess to be generated.

To summarize, the present invention relates to an electrode guide 1 or a method for the spark-erosion of workpieces. Said electrode guide 1, consisting of a two-piece, prism-shaped 2, 3 guide with a pre-tensioning device 6, enables an electrode 4 to be guided in a play-free manner, thus allowing the production of bores that is accurate to within 1  $\mu\text{m}$ . A pivoting device 10 for pivoting the electrode guide 1 and an alignment device 14 for the parallel displacement of said electrode guide 1 are also provided, enabling the production of conical bores.

The above description of the exemplary embodiments according to the present invention serves only for illustration purposes and not to restrict the invention. Various changes and modifications are possible within the context of the invention, without departing from the scope of the invention and its equivalents.